Reports on Work in Support of NASA's Tracking and Communication Division

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NASA Johnson Space Center
Engineering Directorate
Tracking and Communications Division

Research Institute for Computing and Information Systems
University of Houston-Clear Lake

INTERIM REPORT

The RICIS Concept

The University of Houston-Clear Lake established the Research Institute for Computing and Information Systems (RICIS) in 1986 to encourage the NASA Johnson Space Center (JSC) and local industry to actively support research in the computing and information sciences. As part of this endeavor, UHCL proposed a partnership with JSC to jointly define and manage an integrated program of research in advanced data processing technology needed for JSC's main missions, including administrative, engineering and science responsibilities. JSC agreed and entered into a continuing cooperative agreement with UHCL beginning in May 1986, to jointly plan and execute such research through RICIS. Additionally, under Cooperative Agreement NCC 9-16, computing and educational facilities are shared by the two institutions to conduct the research.

The UHCL/RICIS mission is to conduct, coordinate, and disseminate research and professional level education in computing and information systems to serve the needs of the government, industry, community and academia. RICIS combines resources of UHCL and its gateway affiliates to research and develop materials, prototypes and publications on topics of mutual interest to its sponsors and researchers. Within UHCL, the mission is being implemented through interdisciplinary involvement of faculty and students from each of the four schools: Business and Public Administration, Education, Human Sciences and Humanities, and Natural and Applied Sciences. RICIS also collaborates with industry in a companion program. This program is focused on serving the research and advanced development needs of industry.

Moreover, UHCL established relationships with other universities and research organizations, having common research interests, to provide additional sources of expertise to conduct needed research. For example, UHCL has entered into a special partnership with Texas A&M University to help oversee RICIS research and education programs, while other research organizations are involved via the "gateway" concept.

A major role of RICIS then is to find the best match of sponsors, researchers and research objectives to advance knowledge in the computing and information sciences. RICIS, working jointly with its sponsors, advises on research needs, recommends principals for conducting the research, provides technical and administrative support to coordinate the research and integrates technical results into the goals of UHCL, NASA/JSC and industry.

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RICIS Preface

This research was conducted under auspices of the Research Institute for Computing and Information Systems by Dr. Terry Feagin and Dr. Anthony A. Lekkos of the University of Houston - Clear Lake. Dr. T. F. Leibfried served as RICIS research coordinator.

Funding was provided by the Tracking and Communications Division, Engineering Directorate, NASA/JSC through Cooperative Agreement NCC 9-16 between the NASA Johnson Space Center and the University of Houston-Clear Lake. The NASA research coordinator for this activity was Oron L. Schmidt, of the Tracking and Communications Division, Engineering Directorate, NASA/JSC.

Report on Work in Support of NASA's Tracking and Communication Division

by T. Feagin

This is a report on the research conducted during the period October 1, 1991 through December 31, 1991. The research can be divided into primarily two areas:

1. Generalization of the FIBS (Fault Isolation using Bit Strings) technique to permit fuzzy information to be used to isolate faults in the tracking and communications systems of the Space Station, and

2. A study of the activity that should occur in the on-board systems in order to attempt to recover from failures that are external to the Space Station.

The research on the first topic has advanced to the point where an Ada computer program has been written that accepts a set of sensor readings (or various levels of symptoms that may be present) and produces a resulting diagnosis. A level of confidence in this diagnosis is also provided. A presentation was made to the Tracking and Communication Division and the slides are attached.

The research on the second topic is still in an early stage. At this point, we have studied the so-called Scenario #2, in which communication with the ground has been lost and all indications are that the problem is external to the Space Station. So far we have established that:

a) there is a time, t_0, at which the loss of communications happened,
b) there is another time, t_1, at which the Space Station systems are able to detect the loss of communications,

c) there is another time, t_2, at which the ground *knows* that the Space Station systems should have detected the loss of communications,
d) usually the ground knows about the loss of communications first,
e) if there is a shuttle team on-board, they may also confirm the loss,
f) there would be a short-term plan and a long-term plan,
g) the long-term plan would begin after a few orbits of trying to re-establish communications,
h) the short-term plan would involve trying HDR (high-data-rate) or LDR (low-data-rate) transmissions with various subsystems and antennae,
i) the long-term plan would probably involve the LDR and the omni antenna,
j) there should be a solid, low-power, receive-only mode for S-band, similar to what JPL does for deep space missions,
k) the cycle of attempted operations would be preset so that both the ground and on-board systems would know what the other system was trying in order to re-establish communications.

At this point, it appears that other scenarios (such as those that would postulate problems in the on-board systems) will be developed, at which time the use of techniques such as fuzzy FIBS would become more useful.

Hopefully, funding for this research will eventually be found and this work can be continued (either by me or someone else). Thanks to everyone who supported this work and especially to Oron Schmidt at NASA.

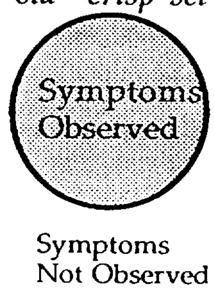
Terry Feagin, Senior Investigator

First Element of Fuzziness --

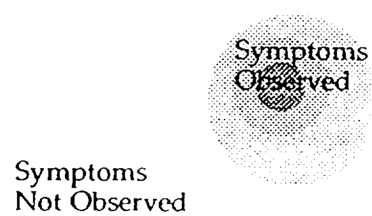
Consider the Fuzzy Set of

Symptoms Observed

old crisp set approach



new fuzzy set approach



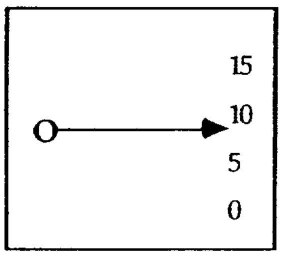
In classical set theory, the degree of membership is either 0 (is not a member) or 1 (is a member). In fuzzy set theory, it is possible to have fractional membership (between 0 and 1).

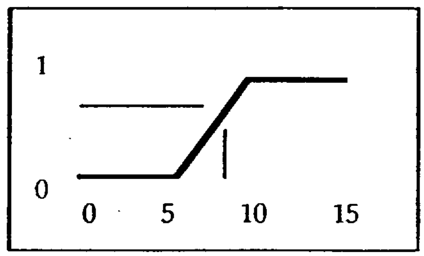
Suppose we have a sensor reading that can range between 0 and 15 volts. If the reading is below 5, everything is okay. If the reading is above 10 volts, we say that the sensor reading is out-of-range. If the reading is between 5 and 10 volts, we are not sure.

Fuzzy set theory allows us to consider directly the issue of whether or not we have a symptom. We simply assign a value between 0 and 1 for those readings between 5 and 10 volts.

The Degree of a Symptom

So, we introduce the concept of the *degree* d of a symptom. For previous example, then:





we could use the function:

$$
\begin{array}{ll}
d = 0, & \text{for } 0 < v < 5 \\
d = (v-5)/5, & \text{for } 5 < v < 10 \\
d = 1, & \text{for } 10 < v < 15
\end{array}
$$

or some similar continuous function.

$d = 0$ means symptom is definitely not present

$d = 1$ means symptom is definitely present

Example Fault Scenario

Symptoms 4 and 2 are observed. So, obviously a fault is detected, and we begin to try to diagnose the problem. We obtain, therefore, the bitwise conjunction of S_4 and S_2 and (not S_1) and (not S_3) to obtain the result bitstring R:

old strings		*new strings*
$\cancel{S_4 = \{1\ 1\ 0\ 1\ 1\}}$	$\rightarrow$	$\{d_4\ \ d_4\ \ 1\text{-}d_4\ \ d_4\ \ d_4\}$
$\cancel{S_2 = \{1\ 1\ 1\ 0\ 0\}}$	$\rightarrow$	$\{d_2\ \ d_2\ \ d_2\ \ 1\text{-}d_2\ \ 1\text{-}d_2\}$
$\cancel{\sim S_1 = \{0\ 1\ 1\ 1\ 1\}}$	$\rightarrow$	$\{1\text{-}d_1\ \ d_1\ \ d_1\ \ d_1\ \ d_1\}$
$\cancel{\sim S_3 = \{1\ 1\ 1\ 0\ 1\}}$	$\rightarrow$	$\{d_3\ \ d_3\ \ d_3\ \ 1\text{-}d_3\ \ d_3\}$

new result

$$\boxed{R = \{\ d_4 d_2 (1\text{-}d_1)\, d_3,\ d_4 d_2 d_1 d_3,\ (1\text{-}d_4) d_2 d_1 d_3,\ d_4 (1\text{-}d_2) d_1 d_3\}}$$

old result was $R = \{0\ 1\ 0\ 0\ 0\}$

which is to be interpreted to indicate that the problem is a dead battery.

The Degree of the Problem-Symptom Relationship

The second element of fuzziness that we introduce is in the relationship between a problem (or disorder) and its possible resulting symptoms (or manifestations).

For symptom i and problem k, the relationship is measured by the variable S_{ik}, which will take on values between 0 and 1 according to the strength of the causal relationship between the problem and the symptom. If there is a very strong relationship (i.e., if problem k almost always causes symptom i), then a S_{ik} is assigned a value near 1. If there is a very weak relationship (i.e., if problem k almost never can be seen as a cause for symptom i), then a value near zero is assigned.

If there is no known relationship, then S_{ik} is set to zero.

Note: One of the difficulties posed by the fuzzy set approach to the fault isolation problem is obtaining reasonable values for the S_{ik} parameters. Also, for large systems, the storage requirements may be excessive (unless shortcuts are used).

The Warm Fuzzies

Now the question becomes how to combine the two fuzzy values d_i (the degree to which symptom i is observed at some point in time) and S_{ik} (the degree to which the i-th symptom can be related to the k-th problem) and what to do with the result.

In order to determine the extent to which the k-th problem might be responsible, we form the product:

$$R_k = \prod_i (1 - S_{ik} - d_i + 2\, S_{ik}\, d_i)$$

These values are then sorted so the result is a list of possible single-point failures that could cause the observed symptoms in order of "likelihood."

Some sample problems and their symptoms

For problem number 141 KP_AA_A , the symptoms are:

149 KP_ALPHA_GMC_A
172 KP_BETA_GMC_A
145 KP_AA_HEATER_A
152 KP_AL_ANT_ANGA
174 KP_BE_ANT_ANGA

For problem number 75 KN2_BSPT , the symptoms are:

111 KN2_HFM_BSPT2_IL
79 KN2_BSPT_HFM2_OL
78 KN2_BSPTXMDM2_IL
76 KN2_BSPTBSPV2_OL
82 KN2_BSPVBSPT2_IL

For problem number 81 KN2_BSPV , the symptoms are:

112 KN2_HFM_BSPV2_IL
82 KN2_BSPVBSPT2_IL
83 KN2_BSPV_HFM2_OL

```
 Enter number of symptoms observed: 5
 Enter symptom observed: 149
 Enter degree of presence: 1.0
 Enter symptom observed: 172
 Enter degree of presence: 1.0
 Enter symptom observed: 145
 Enter degree of presence: 1.0
 Enter symptom observed: 152
 Enter degree of presence: 1.0
 Enter symptom observed: 174
 Enter degree of presence: 1.0
 Number of symptoms observed is            5
Diagnosis starting...
SUSPECT1
        141 is the physical problem  or cause to extent 8.1451E-01

          1
KP_AA_A


 Enter number of symptoms observed: 5
 Enter symptom observed: 149
 Enter degree of presence: 0.8
 Enter symptom observed: 172
 Enter degree of presence: 0.7
 Enter symptom observed: 145
 Enter degree of presence: 0.9
 Enter symptom observed: 152
 Enter degree of presence: 0.8
 Enter symptom observed: 174
 Enter degree of presence: 0.8
 Number of symptoms observed is            5
Diagnosis starting...
SUSPECT1
        141 is the physical problem  or cause to extent 3.1044E-01

          1
KP_AA_A


 Enter number of symptoms observed: 4
 Enter symptom observed: 149
 Enter degree of presence: 0.7
 Enter symptom observed: 172
 Enter degree of presence: 0.6
 Enter symptom observed: 145
 Enter degree of presence: 0.9
 Enter symptom observed: 152
 Enter degree of presence: 0.8
 Number of symptoms observed is            4
Diagnosis starting...
SUSPECT1
        141 is the physical problem  or cause to extent 1.5446E-02

          1
KP_AA_A
```

```
 Enter number of symptoms observed: 3
 Enter symptom observed: 149
 Enter degree of presence: 0.99
 Enter symptom observed: 172
 Enter degree of presence: 0.99
 Enter symptom observed: 174
 Enter degree of presence: 0.99
 Number of symptoms observed is          3
Diagnosis starting...
SUSPECT1
        141 is the physical problem  or cause to extent 4.1662E-02

          1
KP_AA_A
 Enter number of symptoms observed: 1
 Enter symptom observed: 149
 Enter degree of presence: 0.999
 Number of symptoms observed is          1
Diagnosis starting...
SUSPECT1
        141 is the physical problem  or cause to extent 1.1864E-04

          1
KP_AA_A
```

```
 Fuzzy FIBS (version 5.8) is at your service ...
  Have you got any exciting jobs for me today ?
 DEBUG level is set to           1
 What is the desired threshold for faults ? 0.00001
 OK PIPELESS Version ..let's go...
 Enter number of symptoms observed: 8
 Enter symptom observed: 111
 Enter degree of presence: 0.9
 Enter symptom observed: 79
 Enter degree of presence: 0.9
 Enter symptom observed: 78
 Enter degree of presence: 0.9
 Enter symptom observed: 76
 Enter degree of presence: 0.9
 Enter symptom observed: 82
 Enter degree of presence: 0.99
 Enter symptom observed: 112
 Enter degree of presence: 0.9
 Enter symptom observed: 83
 Enter degree of presence: 0.99
 Enter symptom observed: 82
 Enter degree of presence: 0.99
 Number of symptoms observed is          8
Diagnosis starting...
SUSPECT1
         75 is the physical problem  or cause to extent 5.1473E-04

         81 is the physical problem  or cause to extent 7.6151E-05

          2
KN2_BSPT
KN2_BSPV
```

Report

on

Work in Support of NASA's

Tracking & Communication Division

Dr. Anthony A. Lekkos
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October 1, to December 31, 1991